Arquivos do Museu Nacional, Rio de Janeiro, v.65, n.4, p.505-510, out./dez.2007
ISSN 0365-4508

A PRESUMED TITANOSAURIAN VERTEBRA FROM THE LATE CRETACEOUS OF NORTH ISLAND, NEW ZEALAND [1]

(With 2 figures)

RALPH E. MOLNAR [2]
JOAN WIFFEN [3]

ABSTRACT: A bone recovered from the Upper Cretaceous Maungataniwha Sandstone of North Island, New Zealand, appears to be an incomplete titanosaurian caudal centrum. The proportions of the apparently procoelous centrum suggest that it is a middle caudal. This indicates the presence of a titanosaurian sauropod in Campanian-Maastrichtian New Zealand. At this time, titanosaurians are known from South America, Africa, India, Laurasian Asia, Europe, and North America. Palaeozoogeographic considerations suggest that titanosaurians were also present in Antarctica.

Key words: Sauropoda. Titanosauria. New Zealand. Cretaceous. Maungataniwha Sandstone.

RESUMO: Uma possível vértebra de titanossauro do Cretáceo Superior de North Island, Nova Zelândia.
Um osso procedente do Arenito Maungataniwha do Cretáceo Superior de North Island, Nova Zelândia, parece ser um centro caudal incompleto de titanossauro. As proporções dessa vértebra caudal, aparentemente procélica sugerem tratar-se de uma caudal média. Isso indica a ocorrência de um saurópode titanossauro do Campaniano-Maastrichtiano da Nova Zelândia. Durante esse espaço de tempo, titanossauros habitaram a América do Sul, África, Índia, Laurásia asiática e América do Norte. Inferências paleozoogeográricas sugerem que titanossauros também viveram na Antártica.

Palavras-chave: Sauropoda. Titanosauria. Nova Zelândia. Cretáceo. Arenito Maungataniwha.

INTRODUCTION

In 1999, the junior author prepared a piece of bone found when splitting a calcareous concretion from the Upper Cretaceous Maungataniwha Sandstone, of North Island, New Zealand. It was found at the Mangahouanga Str. site Map Ref. V19 420-469, by J. Wiffen on 23 October 1999. The specimen, CD.586, is held in the New Zealand Geological & Nuclear Sciences Collections, Lower Hutt. This bone seems to be part of a procoelous or opisthocoelous vertebral centrum. We believe that it is probably an incomplete procoelous sauropod middle caudal centrum. Thus, this is the first sauropod material from New Zealand that can be identified to a level below Sauropoda and the first report of a titanosaurian from New Zealand.

RESULTS AND DISCUSSION

Occurrence

The concretion was collected from the Maungataniwha Sandstone, exposed in the valley of Mangahouanga Stream, near Hawke's Bay, North Island (Fig.1A). The Maungataniwha Sandstone appears to have been an estuarine deposit (Isaac *et al.*, 1991; Moore, 1991) on the eastern coast of Late Cretaceous New Zealand. The sandstone is Piripauan-Haumurian (Campanian-Maastrichtian) in age, but only the lower quarter is definitely Piripauan (approximately Campanian) in age, the higher levels being Piripauan or Haumurian (Moore, 1987).

From a study of the dinoflagellates at the site the age is estimated to be 73 million years (Wilson & Moore 1988; Young, 1999). Thus we consider the specimen to date from approximately the Campanian-Maastrichtian boundary.

This unit yields both a near-shore marine vertebrate fauna (Wiffen, 1981; 1983; Wiffen & Moisley, 1986) and bones of terrestrial vertebrates (Wiffen, 1996, and citations therein), as well as a few insects (Craw & Watts, 1987; Wiffen, 1996). The terrestrial vertebrate fauna includes pterosaurs (Wiffen & Molnar, 1988), non-avian theropods (Molnar & Wiffen, 1994), possibly an avian (Scarlett & Molnar, 1984), an ornithopod (Wiffen & Molnar, 1989), a nodosaur

[1] Submitted on September 14, 2006. Accepted on November 22, 2007.
[2] Research Associate. Museum of Northern Arizona. 3101 North Fort Valley Road. Flagstaff, Arizona 86001. U.S.A.
[3] 16 Mason Retirement Village. 18 Durham Drive, Havelock North. New Zealand

(MOLNAR & WIFFEN, 1994), a sauropod (MOLNAR & WIFFEN, 1994) and, possibly, a freshwater turtle (WIFFEN, 1996) – none of these identifiable more exactly.

The report of a sauropod rests on a single incomplete bone, a piece of rib 380mm long, and probably deriving from a bone a meter or more in length. The size, degree of curvature and form and position of a flange-like shelf along the lateral margin of the bone all more closely match the situation seen in some sauropod dinosaurs (MOLNAR & WIFFEN, 1994), than in any other large Cretaceous tetrapods.

COMPLETENESS

In order to facilitate describing the completeness of this element, the conclusion that it represents a sauropod caudal will be assumed. The posterior articular face, a small part of the dorsal region and much of the left side are preserved (Fig.2A-2D). Most of the surficial bone is missing, revealing a coarse spongy texture, but in two places, both on the left side of the bone, small patches (of at most 10 by 25mm) of lamellar bone are exposed. The posterior face, although worn, shows lamellar bone over at least 75% of the surface, indicating that this region preserves its original form. A concave surface anteriorly may represent part of the anterior articular face.

TAPHONOMY

The bone was completely enclosed in the concretion and was severely worn when exposed during acid preparation, indicating that the breakage and wear occurred prior to burial, or at least lithification of the sediments. Bones of marine saurians found at this site do not show comparable wear (unless exposed at the surface of a concretion). The condition of the caudal suggests that it was exposed subaerially for some time prior to its transport into the area where it was preserved, and hence that it probably derived from a land-dwelling, rather than a marine, animal.

DESCRIPTION

The form of the bone as preserved is basically that of a low, truncate cone, the condyle, from which projects a thick, flattened shelf with a mildly concave face at the end away from the condyle (Fig.2A-2D).

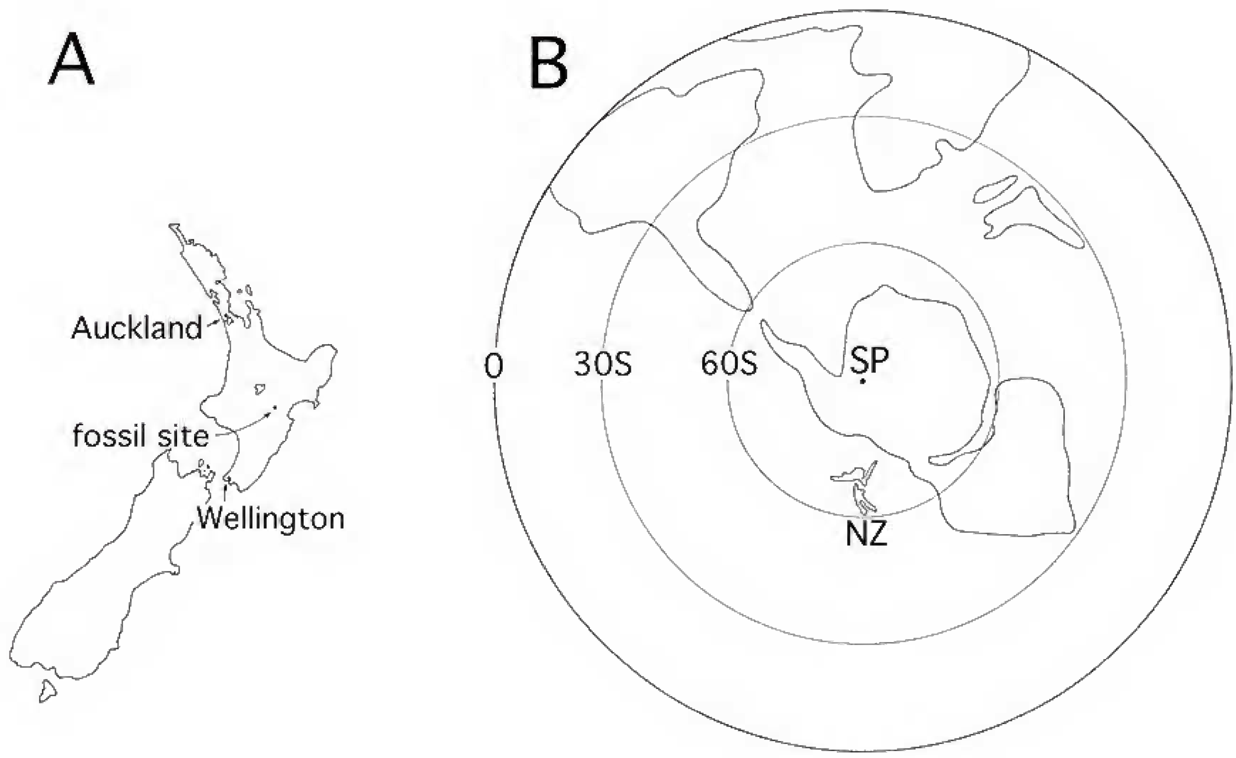

Fig.1. (A) New Zealand, showing the location of the exposures of the Maungataniwha Sandstone, at Mangahouanga Stream, North island. (B) The palaeoposition of New Zealand (NZ) during the Maastrichtian, in south polar projection, based on COOPER *et al.* (1982). SP: South Pole. (After MOLNAR & WIFFEN, 1994).

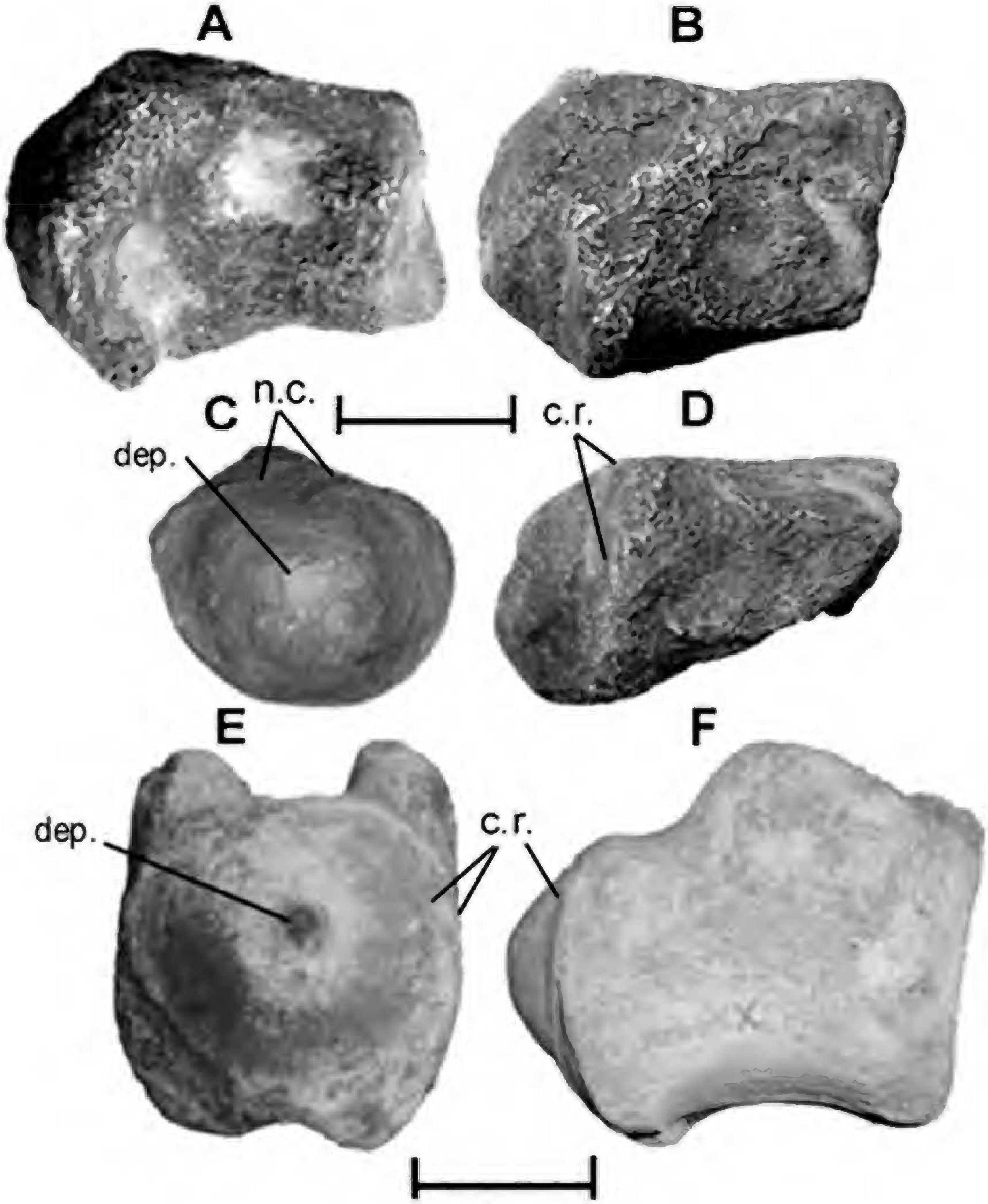

Fig.2. The fossil titanosaurian caudal centrum (CD.586) from Mangahouanga Stream (A-D) compared with an unidentified titanosaurian caudal (MACN unnumbered) from Argentina (E-F). (A) Ventral view, showing two cavities (light regions) in the centrum; (B) dorsal view; (C) posterior view; (D) right lateral view; (E) posterior view; (F) left lateral view, reversed for comparison. The conical forms of the condyles can be seen in outline in A, B, D, and F. The depression at the apex of the condyle of CD.586 retains some matrix and hence is light in color, but that of the MACN caudal is dark from shadow. The photos are of a cast of the specimen. Abbreviations: (c.r.) circumferential rim; (dep.) apical depression; (n.c.) base of neural canal. Scale bars = 50mm.

As mentioned above, this shelf is composed of spongy bone, and the condyle is surfaced with lamellar bone. The condyle is almost conical in form, with a small, but distinct, depression of 17 by 16mm at the apex. One segment of the edge of the condyle is indented by a shallow groove. Unlike the rest of the edge, spongy bone is exposed here. This presumably indicates the posterior termination of the neural canal, and is the basis for identifying the dorsal direction of the bone (Fig.2C). In two places around its circumference, the condyle retains a kind of flange or rim 14mm wide (measured radially parallel to its surface), altogether circumscribing about half of the circumference (Fig.2D). Viewed from above or below, the slopes of the condyle are straight and make an angle of about 85°. From the side, the dorsal slope is straight, and the ventral slightly rounded, but this is due to erosion along the ventral edge, where spongy bone is exposed. These slopes make an angle of 90°.

The articular face is about 91mm broad, and was at least 70mm deep. If the rim continued all around the condyle with the same width, the height would have been approximately 95mm. If the smoothly concave surface represents part of the anterior articular face, then the length of the centrum would have been approximately 122mm, and the proportions those of a middle caudal centrum.

The broken surface of the body of the centrum suggests that two internal cavities were present, or perhaps a single subdivided cavity (Fig.2A). If the groove mentioned above indicates the neural canal, then the septum between the two chambers would be orientated almost in the sagittal plane (deviating by about 10°).

Identification

The Maungataniwha Sandstone is a marine unit that has yielded sauropterygian, mosasaurian, and turtle remains: could this specimen represent one of these? This seems unlikely. Cretaceous sauropterygians are not known to have had procoelous or opisthocoelous vertebrae. The only well-preserved part of the specimen is the condyle, so only condylar characters can be used in the comparisons. In mosasaur vertebrae generally the condyle is more nearly hemispherical in form, and the central depression and rim are absent (see, for example, figures in Lingham-Soliar, 1994a, 1994b; Wiffen, 1980, 1990).

The specimen seems quite large for a turtle, although giant marine turtles (e.g., *Archelon* and *Cratochelone*) were present during the Cretaceous. Turtles may have procoelous or opisthocoelous cervicals or caudals (Romer, 1956). The cervicals of marine turtles lack the condylar rim and central depression (e.g., plates 31-33 of Zangerl, 1960). Cretaceous marine turtle caudals in the collections of the Museum of Northern Arizona suggest that the condyles were substantially less projecting, and bordered ventrally by a more extensive flat face of the centrum. Furthermore, we feel that the great size of the animal to be inferred if this bone represents a cervical or caudal vertebra of a marine turtle, makes identification as dinosaurian the more parsimonious.

The size of this piece alone suggests that it might be dinosaurian. Of dinosaurs, only sauropods exhibit procoelous vertebrae, but some theropods and ornithopods, as well as sauropods, have opisthocoelous vertebrae. Small, basal ornithopods have weakly opisthocoelous (or non-opisthocoelous) centra (Norman *et al.*, 2004) and hence differ from that described here. Large ornithopods such as *Iguanodon* (Norman, 1980, 1986), *Ouranosaurus* (Taquet, 1976), *Muttaburrasaurus* (Molnar, 1996), and hadrosaurs (Lull & Wright, 1942) have opisthocoelous cervicals and anterior dorsals, although those of *Muttaburrasaurus* are but mildly opisthocoelous. Again, as with the forms previously considered, the condyle is not conical, but rounded, and lacks the circumferential rim and central depression.

Large theropods also have opisthocoelous cervicals (Holtz *et al.*, 2004), but again the condyles differ in form, and lack the rim and central depression. Sauropod cervicals lack the circumferential rim and central depression of the condyle, although some cervicals (e.g., those of *Rhoetosaurus brownei*) may have a central condylar projection, and they often have more extensive internal chambers than seen here. Anterior dorsals may be opisthocoelous, and although some may have conical condyles (*Saltasaurus loricatus*, Pl.26, Powell, 2003) or appear to have circumferential rims (*Neuquensaurus australis*, Lam. 3, Huene, 1929), these characters do not seem to occur together, and none show a central depression of the condyle. As far as we can determine from the literature, conical condyles and rims (or apparent rims), occur only in titanosaurians.

The opisthocoelous caudals of *Opisthocoelicaudia skarzynskii* lack the circumferential rim, although they do seem to have a conical, rather than rounded, condyle (Borsuk-Bialynicka, 1977). Published figures suggest that procoelous titanosaurian vertebrae may exhibit rounded or conical condyles. For example, viewed from the side the condyles of at least some middle caudals of *Iuticosaurus valdensis* (Fig.19 of

WILSON & UPCHURCH, 2003), *N. australis* (Pl.58 of POWELL, 2003) and *S. loricatus* (Pls.52-53 of POWELL, 2003) appear hemispherical (or nearly so) in form, and at least some of *Iuticosaurus lydekkeri* (Fig.19 of WILSON & UPCHURCH, 2003), *Laplatasaurus araukanicus* (Figs.8-9 of Lam.22 of HUENE, 1929), *Aeolosaurus rionegrinus* (Pl.11 of POWELL, 2003) and *Magyarosaurus dacus* (Fig.19 of WILSON & UPCHURCH, 2003) appear to be conical. So far as we have been able to determine conical condyles, circumferential rims and central depressions are found together only in titanosaurian caudals. Circumferential rims may be seen in *Magyarosaurus dacus* (Fig.19 of WILSON & UPCHURCH, 2003), *S. loricatus* (POWELL, 2003), and *N. australis* (POWELL, 2003), and a central depression in a caudal referred to *Magyarosaurus hungaricus* (HUENE, 1932).

Some titanosaurian caudals in the Museo Argentino de Ciencias Naturales (MACN), particularly MACN-RN147 (attributed to *Aeolosaurus*) and MACN 15131 (*Laplatasaurus*), show conical or nearly conical condyles. Those of MACN-RN147 lack apical depressions, but one of MACN 15131 shows such a depression, as do several others, including the middle caudal of MACN 15084 and one designated 'Los Alamitos 89' (both unidentified titanosaurians). This vertebra, as well as an unnumbered centrum from the old collections (Fig.2E-F), show both a conical condyle and circumferential rim. It is this similarity that suggests to us that the Maungataniwha bone most likely represents an incomplete titanosaurian middle caudal vertebra.

SIGNIFICANCE

The presence of titanosaurians in Cretaceous New Zealand is not especially surprising, although actually finding a (likely) specimen is gratifying. During most of the Cretaceous, New Zealand was part of what is now Antarctica, separating from it at approximately the beginning of the Campanian (COOPER & MILLENER, 1993). Thus the Maungataniwha tetrapods lived after the separation, and represent an insular fauna from high southern latitudes (Fig.1B) (MOLNAR & WIFFEN, 1994). Late Cretaceous titanosaurians are known from central and western Europe, the U.S.A., China, Mongolia, India, north Africa, Madagascar, South America (WILSON & UPCHURCH, 2003), and Australia (MOLNAR, 2001). So, their appearance in New Zealand (then part of Antarctica) between the African and South American regions of Gondwanaland on the one hand, and the Australian on the other, is not unexpected.

Of more local interest is that this is only the second dinosaurian specimen from New Zealand that can be identified to a lower systematic level than Sauropoda. In view of the lack of knowledge of the details of the distribution among titanosaurians of the characters used here to identify the bone, no special relationship to forms such as *Aeolosaurus* and *Laplatasaurus* can be proposed without the discovery of further material.

Furthermore, WILSON & UPCHURCH (2003) indicate that the distributions of supposedly widespread titanosaurian taxa (e.g., *Laplatasaurus* and *Titanosaurus*) were much less broad than previously believed. However, the occurrence in New Zealand makes the habitation of Antarctica by related sauropods in the Late Cretaceous nearly certain.

ACKNOWLEDGMENTS

We wish to thank Dr. José Bonaparte for his kind permission to study and photograph titanosaurian caudals in the collections of the Museo Argentino de Ciencias Naturales. Alexander W. A. Kellner helpfully arranged access to titanosaur caudals in the Museu Nacional, Rio de Janeiro. Janet Whitmore Gillette kindly provided access to the marine turtle material in the Museum of Northern Arizona. We also appreciate the assistance of J. Calvo, D. Riff and two anonymous referees. And finally our thanks to Carter, Holt Harvey for continued access to the fossil site.

REFERENCES

BORSUK-BIALYNICKA, M., 1977. A new camarasaurid sauropod *Opisthocoelicaudia skarzynskii* gen.n., sp.n. from the Upper Cretaceous of Mongolia. **Palaeontologia Polonica**, **37**:5-64.

COOPER, R.A.; LANDIS, C.A.; LE MESURIER, W.E. & SPEDEN, I.G., 1982. Geological history and regional patterns in New Zealand and west Antarctica – their paleotectonic and paleogeographic significance. In: CRADDOCK, C. (Ed.) **Antarctic Geoscience**. Madison: University of Wisconsin Press. p.43-53.

COOPER, R.A. & MILLENER, P.R., 1993. The New Zealand biota: historical background and new research. **Trends in Ecology & Evolution**, **8**:429-433.

CRAW, R.D. & WATTS, J.C., 1987. An Upper Cretaceous beetle (Coleoptera) from Hawke's Bay. **Journal of the Royal Society of New Zealand**, **17**:395-398.

HOLTZ, Jr., T.R.; MOLNAR, R.E. & CURRIE, P.J., 2004. Basal Tetanurae. In: WEISHAMPEL, D.B.; DODSON, P. & OSMÓLSKA, H. (Eds.) **The Dinosauria.** 2 Ed. Berkeley: University of California Press., p.71-110.

HUENE, F.R., 1929. Los saurisquios y ornitisquios del Cretácico Argentino. **Annales del Museo de la Plata, 3**:1-194.

HUENE, F.R., 1932. Die fossile Reptil-Ordnung Saurischia, ihre Entwicklung und Geschichte. **Monographien zur Geologie und Paläontologie**, **4**:1-361.

ISAAC, M.J.; MOORE, P.R. & JOASS, Y.J., 1991. Tahora Formation: the basal facies of a Late Cretaceous transgressive sequence, northeastern New Zealand. **New Zealand Journal of Geology and Geophysics**, **34**:227-236.

LINGHAM-SOLIAR, T., 1994a. First record of mosasaurs from the Maastrichtian (Upper Cretaceous) of Zaire. **Paläontologische Zeitschrift**, **68**:259-265.

LINGHAM-SOLIAR, T., 1994b. The mosasaur *Plioplatecarpus* (Reptilia: Mosasauridae) from the Upper Cretaceous of Europe. **Bulletin van het Koninklijk Belgisch Institut voor Natuurwetenschappen, 64**:177-211.

LULL, R.S. & WRIGHT, N.E., 1942. Hadrosaurian dinosaurs of North America. **Geological Society of America, Special Paper**, **40**:1-242.

MOLNAR, R.E., 1996. Observations on the Australian ornithopod dinosaur, *Muttaburrasaurus*. **Memoirs of the Queensland Museum, 39**:639-652.

MOLNAR, R.E., 2001. A reassessment of the phylogenetic position of Cretaceous sauropod dinosaurs from Queensland, Australia. In: LEANZA, H.A. (Ed.) **Publicación Especial of the International Symposium on Mesozoic Terrestrial Ecosystems, 7**. Buenos Aires. p.139-144.

MOLNAR, R.E. & WIFFEN, J., 1994. A Late Cretaceous polar dinosaur fauna from New Zealand. **Cretaceous Research**, **15**:689-706.

MOORE, P.R., 1987. Stratigraphy and structure of the Te Hoe-Waiau river area western Hawkes Bay. **New Zealand Geological Survey Records**, **18**:4-12.

MOORE, P.R., 1991. Reply to: A reassessment of the depositional environment for the conglomeratic facies, Maungataniwha Sandstone, western Hawke's Bay. **New Zealand Journal of Geology and Geophysics**, **34**:563-564.

NORMAN, D.B., 1980. On the ornithischian dinosaur *Iguanodon bernissartensis* of Bernissart (Belgium). **Koninklijk Belgisch Institut voor Natuurwetenschappen, Verhandeling, 178**:1-105.

NORMAN, D.B., 1986. On the anatomy of *Iguanodon atherfieldensis* (Ornithischia: Ornithopoda). **Bulletin van het Koninklijk Belgisch Institut voor Natuurwetenschappen**, **56**:281-372.

NORMAN, D.B.; SUES, H.-D.; WITMER, L.M. & CORIA, R.A., 2004. Basal Ornithopoda. In: WEISHAMPEL, D.B.; DODSON, P. & OSMÓLSKA, H. (Eds.) **The Dinosauria.** 2 Ed. Berkeley: University of California Press. p.393-412.

POWELL, J.E., 2003. Revision of South American titanosaurid dinosaurs: palaeobiological, palaeobiogeographical and phylogenetic aspects. **Records of the Queen Victoria Museum**, **111**:1-173.

ROMER, A.S., 1956. **Osteology of the Reptiles**. Chicago: University of Chicago Press. 772p.

SCARLETT, R.J. & MOLNAR, R.E., 1984. Terrestrial bird or dinosaur phalanx from the New Zealand Cretaceous. **New Zealand Journal of Zoology, 11**:271-275.

TAQUET, P., 1976. **Géologie et Paléontologie du Gisement de Gadoufaoua: Aptien du Niger**. Paris: Centre National de la Recherche Scientifique. 191 p.

WIFFEN, J., 1980. *Moanasaurus*, a new genus of marine reptile (Family Mosasauridae) from the Upper Cretaceous of North Island, New Zealand. **New Zealand Journal of Geology and Geophysics, 23**:507-528.

WIFFEN, J., 1981. The first Late Cretaceous turtles from New Zealand. **New Zealand Journal of Geology and Geophysics, 24**:293-299.

WIFFEN, J., 1983. The first record of *Pachyrhizodus caninus* Cope (Order Clupeiformes) from the Late Cretaceous of New Zealand. **New Zealand Journal of Geology**, **261**:109-119.

WIFFEN, J., 1990. New mosasaurs (Reptilia; Family Mosasauridae) from the Upper Cretaceous of North Island, New Zealand. **New Zealand Journal of Geology and Geophysics, 33**:678-685.

WIFFEN, J., 1996. Dinosaurian palaeobiology: a New Zealand perspective. **Memoirs of the Queensland Museum, 39**:725-731.

WIFFEN, J. & MOISLEY, W.L., 1986. Late Cretaceous reptiles (Family Elasmosauridae & Pliosauridae) from the Mangahouanga Stream of New Zealand. **New Zealand Journal of Geology and Geophysics, 291**:205-252.

WIFFEN, J. & MOLNAR, R.E., 1988. First pterosaur from New Zealand. **Alcheringa, 12**:53-59.

WIFFEN, J. & MOLNAR, R.E., 1989. An ornithopod dinosaur from New Zealand. **Geobios, 23**:507-528.

WILSON, G.J. & MOORE, P.R., 1988. Cretaceous-Tertiary boundary in the Te Hoe River area, western Hawke's Bay, New Zealand. **New Zealand Geological Survey Records, 33**:34-37.

WILSON, J.A. & UPCHURCH, P., 2003. A revision of *Titanosaurus* Lydekker (Dinosauria – Sauropoda), the first dinosaur genus with a 'Gondwanan' distribution. **Journal of Systematic Palaeontology, 1**:125-160.

YOUNG, M., 1999. Dating the dinosaurs. Palynology of the Maungataniwha Sandstone, northwestern Hawke's Bay. **Geological Society of New Zealand, 107A**:178.

ZANGERL, R., 1960. The vertebrate fauna of the Selma Formation of Alabama. Part V: an advanced cheloniid sea turtle. **Geology Memoirs, 3**:279-312.